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A two-degree-of-freedom PI controller based on events

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ABSTRACT

In this paper, a completely event-based two-degree-of-freedom proportional–integral controller is presented. The architecture of the controller is based on event-based decoupled solutions for the set-point following and the load disturbance rejection tasks. For the first task, the solution is a design procedure that, by considering a first-order-plus-dead-time model of the process and a predesigned open-loop control action, produces an event-based feedforward controller that provides the required process variable transition with just two events. The second task is solved by applying two separate event-based proportional and integral control actions. Because the two tasks are initially solved independently, two solutions for coupling them are described. Illustrative examples of the performance of the controller are included as well as experimental results.

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1. Introduction

It is well known that in some processes a small control error does not constitute a hard design constraint, but the reduction of the information exchanged between the agents that take part in the control loop (sensors, controllers, actuators) is still one of the tightest requirements. With these demands, one of the most convenient strategies is the use of event-based sampling and control approaches. For this reason, during the last few years event-based sampling and control techniques have attracted special attention from several research groups [1–21]. Indeed, the reduction of the information flow is an especially relevant issue when there are constraints on the communication rate, for instance, when data are exchanged in a distributed control system by wired or wireless networks [22–28]. In these situations, cutting down the traffic load is a key point because the greater the traffic is, the higher the possibility of lost data and stochastic time delays will be [29–31]. This not only prevents the occurrence of large latencies and delay jitter, but also reduces the CPU utilisation. A very well-known assertion in communication networks states that a reduction of the information flow is always welcome, especially if the network is a generic one, such as the Internet, where the channel is shared by many applications. In any case, a sheer reduction of the exchanged traffic is an essential issue in wireless networks and especially in those using battery-powered or limited computational power devices [32,33]. Therefore, the greater the reduction in information flow is, the greater the decrease in the number of computing operations and transmissions required will be, and thus the longer the lifetime of batteries will be.

However, there are drawbacks in using event-based control systems from both the theoretical and practical points of view. First, event-based control systems are in their infancy, and there are many theoretical problems to be addressed. These systems can be classified as stochastic hybrid systems [18] or non-linear systems [9]. Thus, the tuning of these controllers and conditions for global stability, for the absence of limit cycles, etc., are topics that are far from being fully solved yet. In most occasions, conditions for practical stability are just established [12,20]. Second, the implementation is not trivial because most of the data acquisition hardware is time-driven, and event-based sampling approaches must be simulated by fast sampling using a generic Data Acquisition Board (DAB).

In just a few words, it is not the passing of time but the triggering of state events that forces the control agent to act in purely event-based control implementations. Thus, a change in the process output or a state variable is the event that pushes the sensor or the observer, respectively, to communicate with the controller; moreover, events are noted in the controller by the difference between two consecutive error samples or control actions (note that in the controller it is possible to differentiate between input and output events), and the reception of a new control signal triggers the event in the actuator. Hence, the common denominator is the absence of a timer that increments the evolution of the control loop. The previous considerations regarding the terms "purely event-based" and "state events" were introduced because in some cases the control agents must also be advanced by some kind of asynchronous temporal event. A very well-known example is to

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